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Abstract

Remote monitoring is a key element of the new International Atomic Energy Agency strengthened safeguards system. Remote monitoring requires safeguards and surveillance sensors to be networked for continuous unattended collection of information. All information is then concentrated at a central-data collection computer. Monitoring plutonium in bulk-handling facilities, such as reprocessing and Mixed Oxide (MOX) fuel fabrication facilities, uses nondestructive assay neutron instruments installed at key points throughout the facility. These instruments provide continuous measurements that allow the plutonium to be tracked and quantitatively assayed. A critical component in these instruments is the shift register to collect and analyze signals from neutron detectors. A new generation of shift register, called the Advanced Multiplicity Shift Register (AMSR) has been developed by Los Alamos. The AMSR offers the capability to network unattended neutron instrumentation through ethernet or serial connections and also, using its front panel controls and display, the capability for attended mode measurements. The AMSR provides data-filtering algorithms, local data backup, and trigger signals for external sensors such as cameras for real-time monitoring. This paper describes the features, capabilities, and performance of the AMSR.

INTRODUCTION

The shift register circuit introduced by Swansen and Stephens[1] and Boehnel[2] has been the most commonly used electronics for coincidence counting applications over more than a decade. Improvements on this basic circuit design have been developed by Stephens, Swansen, and East.[3] Swansen,[4] and Lambert.[5] More recently, efforts have been made to miniaturize the electronics, include multiplicity circuits, and enhance the capability for a local computer to control the shift register.[6]

Among the efforts being undertaken by the International Atomic Energy Agency (IAEA) to strengthen safeguards is the improvement of efficiency by implementing remote monitoring. Advances in remote monitoring require safeguards and surveillance sensors that can be networked for continuous, unattended collection of information. These sensors and their electronics must meet stringent requirements for data authentication, time synchronization, network connectivity for data transmission and triggers, and must perform with extremely high reliability. A prototype Advanced Multiplicity Shift Register (AMSR) which integrates neutron coincidence counting electronics into a remote-monitoring safeguards system architecture has been developed by Los Alamos National Laboratory at the request of the IAEA. The prototype AMSR was provided to the IAEA for usability and functional testing in October 1998 and was completed in December 1998. IAEA-requested modifications were incorporated into the AMSR design in early 1999. The resulting design has since been licensed to several safeguards equipment manufacturers. This paper describes the prototype AMSR.

AMSR OVERVIEW

The AMSR builds on the foundation of Los Alamos National Laboratory designed Intelligent Shift Register (ISR) and other integrated monitoring hardware.[7] The ISR is an newly designed electronics instrument with embedded firmware called ISR Monitor that resides in the ISR and controls its operation. ISR Monitor is also embedded in the AMSR. All modern, commercially available shift registers provide the capability to be operated under some form of external computer control. Operations to start the shift register, stop it, and read out the acquired data through a serial port are typically supported. The ISR Monitor program goes beyond this by including functionality that will not only run the shift register and readout the acquired data but will also timestamp the data, filter it, store the results, characterize the data, and make real-time decisions for such purposes as issuing a trigger to an external camera. ISR Monitor maintains accumulated data in battery backed-up memory and can dump the data to an external computer upon request.

AMSR HARDWARE

The AMSR contains the ISR's shift register/multiplicity board set, master processor, and low- and high-voltage (HV) supplies as shown in Fig. 1. The AMSR and ISR both contain the advanced Los Alamos shift-register design that provides neutron totals, doubles, and multiplicity information with a timestamp. Both are capable of hosting the circuitry for advanced sampling[8] which decreases measurement times and improves accuracy.

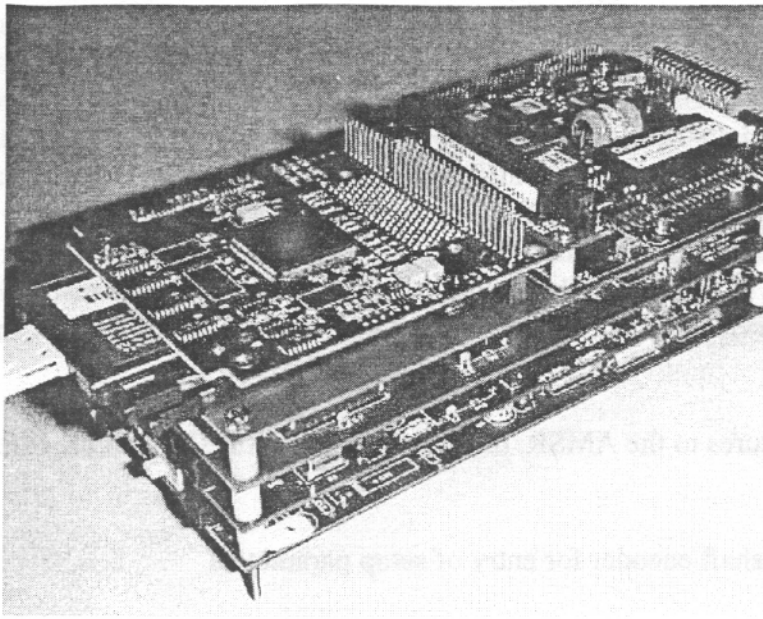

Fig. 1. AMSR board stack showing the Application Board with PC/104 and PCMCIA interface.

AMSR FEATURES

Both the ISR and the AMSR have the following features:

- 4-MHz shift register circuitry
- Advanced sampling circuitry
- Sixteen-deep FIFO type derandomizer
- 36-bit totals synchronous counter
- 48-bit reals plus accidentals (R+A) and accidentals (A) synchronous counters
- Two auxiliary totals scalers
- Adjustable input pulse threshold minimizing noise susceptibility and improving pulse pair resolution
- 256-channel multiplicity counter
- Embedded data-filtering algorithms
- Embedded data-analysis and triggering algorithms
- High-voltage bias supply (0 – 2000 V)
- Data buffer for multiple runs
- Serial port interface
- Data transmission at the request of a host computer over a serial line
- State of health monitoring
- Backward compatibility with many existing shift register command sets
- Full compatibility with IAEA Neutron Coincidence Counting (INCC) software
- Full compatibility with Multi-Instrument Collect (MIC) software

The AMSR adds a new board called the Application Board (AB) to the ISR board stack, also shown in Fig. 1. The AB provides a high-speed hardware interface between the Master Processor and a commercially available 80386/80486 processor card on a PC/104 bus. PC/104 cards can be stacked directly on the AB to add features. Use of the commercially available PC/104 bus standard is a very cost-effective alternative to specially designed processor cards. Not only is the PC/104 a true bus standard which can interface with other readily available cards and devices, but commercial software and device drivers are available and cost effective. For example, a commercially available, low-cost PC/104-PCMCIA card was plugged into the AB stack to obtain the ethernet interface and the flash memory card features. Commercial device drivers were easily and inexpensively loaded into the PC/104 processor to service the added card. A photograph of the board stack is shown in Fig. 1.

The AB adds the following features to the AMSR, differentiating the AMSR from the ISR:

- Front panel display
- "Adjust" knob with optical shaft encoder for entry of setup parameters
- Keypad
- Local/Remote mode selection discrete switch
- Flash memory PCMCIA card slot accessible on the front panel
- Intel® 386 processor running the DOS operating system capable of running authentication and data-encryption software
- 73-MB internal disk-on-chip (DOC) which provides nonvolatile storage for operating systems, programs, and data backup
- Monitor and keyboard ports on the rear panel for debugging purposes
- Stand-alone or unattended network mode operation
- Ethernet port
- +12V backup battery operation
- Flash memory card data storage for data backup

FRONT PANEL DISPLAY AND CONTROLS

Setup of the instrument occurs either through the serial interface while in Remote mode or through the front panel in Local mode. The ISR initially powers up in Remote mode. In Remote mode, an external computer running the MIC[9] software has control of the AMSR. The user has the option to take control from the external collect computer by pressing the Local/Remote mode selection switch on the front panel. Pressing this switch puts the AMSR in Local mode and the front panel can then be used to modify parameters and access data. Once in Local mode, a timer is started that is initialized to a parameter entered while in setup. At the end of the timeout time, the instrument automatically goes back to Remote mode. If the Local/Remote pushbutton is pressed while in Local mode, the ISR goes back to Remote mode.

While in Local mode, the front panel, shown in Fig. 2, displays parameter settings or shift register data depending on the position of the Operate/Setup toggle switch. The Operate/Setup switch only affects operation while in the Local mode. When the switch is flipped down to Setup, the parameters for the run can be modified. While in Setup, the previous run is terminated and the registers are reset. A keypad is configured for viewing the present parameters by scrolling through the screen with the up and down arrows. The ENTER and END keys are used for parameter modification. A rotary-encoded adjust knob is included for user input of parameters. For parameters with a wide range of inputs such as the HV, speed-sensitive software has been developed which adjusts the parameter at a rate proportional to the rotation speed of the knob. Turning the knob rapidly may increment the HV 500 V per turn while turning the knob slowly will vary the HV 32 V per turn.

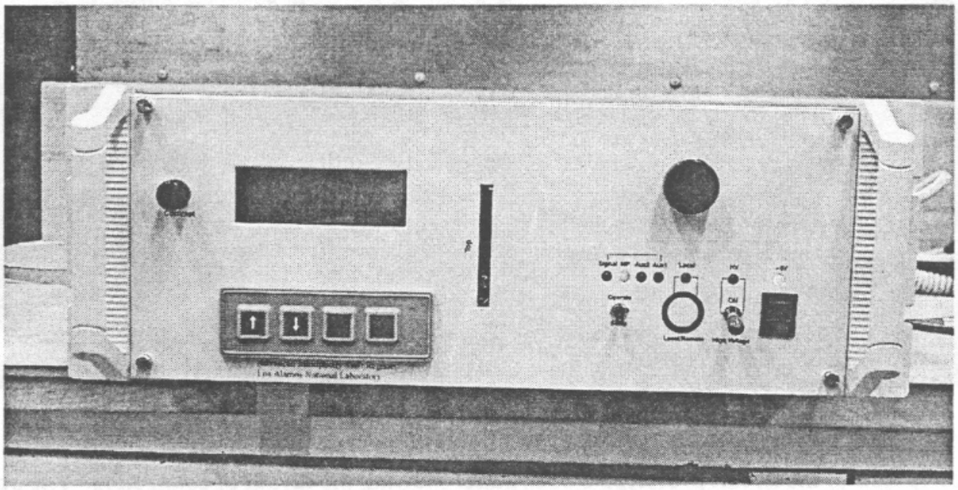

Fig. 2. A view of the AMSR prototype's front panel showing the display, keypad, flash memory card slot, and other controls.

Flipping the switch to Operate configures the keypad for START, STOP, and RESET. The run data can be viewed on the LCD display and the up and down arrows on the keypad can be used to scroll through the data.

The front panel also has indicator LEDs showing the status of the input signals, the processor, and the operating mode.

BACK PANEL CONNECTORS

The AMSR prototype's back panel, shown in Fig. 3, includes connectors for a serial port, a parallel (trigger and time synchronization) port, signal inputs, HV output, +5V output, +12V output (for powering certain preamplifiers), RJ45 ethernet, keyboard, and a VGA monitor. Commercial units will also have a connector for an external backup battery and may contain other features added by the manufacturer.

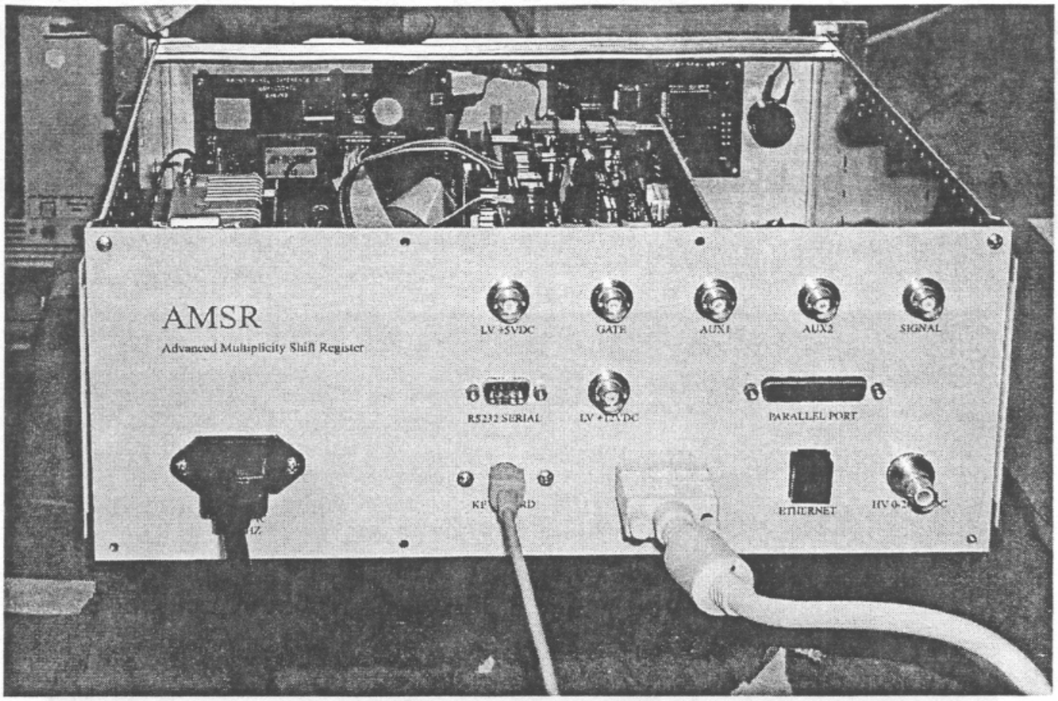

Fig. 3. A view of the AMSR prototype's back panel showing the layout of connectors. The board stack can be seen inside the box.

CONCLUSIONS

The AMSR technology provides the capability to integrate neutron coincidence counters into a remote-monitoring system architecture in support of strengthened safeguards. An industry standard PC/104 bus was used, allowing for cost-effective expansion, maintenance, and software upgrades. The AMSR is backward compatible with most existing shift registers, but includes advanced sampling circuits and networking capability.

AKNOWLEDGEMENT

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